Rapidity Asymmetry in High-energy $d + A$ Collisions *

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Recent experiments at the Relativistic Heavy-ion Collider (RHIC) have shown a significant suppression of high p_T hadron spectra in central $Au+Au$ collisions that was predicted as a consequence of parton energy loss or jet quenching in dense matter. In addition, the same mechanism is predicted to produce azimuthal anisotropy in high p_T hadron spectra that was also observed in experiments at RHIC. This is a dramatic departure from the heavy-ion collisions at the SPS energies where no significant suppression of high p_T spectra is observed. Since theoretical studies of parton propagation in a dense medium all show that the parton energy loss induced by multiple scattering is proportional to the gluon density, RHIC data thus indicate an initial gluon density in central $Au+Au$ collisions at the RHIC energies that is much higher than that in a large cold nucleus.

More precise extraction of the parton energy loss from the final hadron suppression in $A+A$ collisions, however, requires the understanding of normal nuclear effects in $p+A$ collisions. As pointed out by many early and recent studies, the high p_T hadron spectra can also be modified by initial multiple scatterings in $p+A$ and $A+A$ collisions giving rise to the observed Cronin effect. Within a multiple scattering model, the high p_T hadron spectra are normally enhanced relative to $p+p$ collisions, except in the kinematic region where the EMC effect is important (The EMC effect is the depletion of parton distributions in $x \sim 0.2-0.8$ in nuclei caused by the nuclear binding effect). Such a normal nuclear enhancement will not affect the interpretation of the hadron suppression in central $A+A$ collisions as a consequence of jet quenching, though inclusion of it is important for more precise extraction of parton energy loss and the initial gluon density.

A very different mechanism was recently proposed for the observed high p_T hadron suppression based on the parton saturation model [**?**] which also predicts a similar suppression in $p+A$ collisions at RHIC, in contrast to the predicted enhancement by the multiple parton scattering model. While such a model is not yet checked against the existing $p+A$ collisions for energies up to $\sqrt{s} = 40$ GeV where enhancement of hadron spectra for $p_T > 2$ GeV/c has been successfully explained by the multiple scattering model, the up-coming data of $d+A$ collisions at RHIC will attest the relevance of parton saturation at the RHIC energies.

In this letter, we point out an additional feature in the rapidity dependence of the Cronin enhancement due to multiple parton scattering in $d+A$ collisions. Such a rapidity dependence was also studied recently by Vitev. However, we predict here a unique rapidity asymmetry of high p_T hadron spectra due to stronger Cronin enhancement in the forward (projectile) region as a result of the transverse momentum broadening of the initial partons inside the projectile. The shape of the rapidity asymmetry will also depend on the nuclear modification of the parton distributions inside a nucleus, in particular at small x. As one decreases p_T, the parton shadowing will reduce the hadron spectra in the forward region, thus changing the rapidity asymmetry. When soft and coherent interactions become dominant at very low $p_T < 1$ GeV/c, the shape of the rapidity asymmetry will be reversed because of the strong suppression of hadron production in the projectile region relative to a superposition of binary $p+p$ collisions. We will calculate the rapidity asymmetry within a perturbative QCD (pQCD) parton model and study the effect of nuclear modification of parton distributions.

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*arhive nucl-th/0303004